Department of Industrial Engineering and Management

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Aalto University | SCIENCE + TECHNOLOGY | WORKING PAPERS

Aalto University publication series
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ISBN 978-952-60-5111-6 (pdf)
ISSN-L 1799-4896
ISSN 1799-4896 (printed)
ISSN 1799-490X (pdf)

Unigrafia Oy
Helsinki
2013

Finland

# Abstract

User innovation is common in many domains, and has been found concentrated in few individuals, lead users. Particularly with regard to a given product or service development project, such rare research subjects can be difficult and resource intensive to identify. Several alternative methods are common in the lead-user identification process, but according to dominant practitioner experience, the searches tend not to follow just one of them, but rather are inclined to involve the integration of several methods. This integration of alternative search methods has not, however, been discussed properly to date. The present state of affairs can make the lead-user identification process appear either as simple recipe following or as a mysterious process. We argue for a realistic middle ground between these extreme depictions, and propose an integrative search strategy labeled "mountaineering" towards users with the sought-after characteristics, lead userness in case of lead users. Through four principal and two supportive cases of mountaineering search, we elaborate some of the alternatives and choices in moving from one search method to another as responses to contingencies in particular searches. This elaboration of actual search experiences complements established depictions of ideal search processes and analytical comparisons between particular search methods.

Keywords: Sequential search, rare subjects, lead-user identification, mountaineering

# 1. Introduction

Users play an increasingly important role in product and service development (e.g. Prahalad & Ramaswamy 2004; von Hippel 2005). Numerous studies have concentrated on identification of user or customer needs and how these needs can be incorporated into products or services (e.g. Hauser & Clausing 1988; Kaulio 1998; Yan et al. 2007). Several studies demonstrate that users can also be a source of new product ideas (e.g. von Hippel 2005; Jeppesen & Frederiksen 2006). Cooperation with lead users[1] and lead-use experts has been shown to be an effective means to gain insight into the trends and solutions available in the user domain and to further transform this knowledge into product and service concepts (e.g. Herstatt & von Hippel 1992; Lilien et al. 2002; Churchill et al. 2009). However, such users tend to be, few and far apart, and one of the main questions remains how to find the right people (e.g. Olson & Bakke 2001; Churchill et al. 2009). Bilgram et al. (2008, 421) conclude that "research in this area indicates that companies are still facing considerable problems in efficiently identifying suitable users". In research on innovations developed by users, identification of lead users is a potent strategy in the quest towards mapping user innovations within a given domain, evaluating designs, and mapping future directions; yet ridden by the same laborious search to find them. The problem does not concern product and service development alone, but finding subjects with rare attributes within poorly mapped search spaces has been a general problem in social sciences writ large (Sudman & Kalton 1986; Atkinson & Flint 2001; von Hippel et al. 2009).

Research in the area has taken considerable efforts to rationalize these search processes in terms of presenting process depictions of ideal steps through which a search would proceed (e.g. Churchill et al., 2009), formalizing some of the strategies developed in doing these searches (von Hippel et al. 2009), as well as in pursuing comparisons and simulations for establishing the efficiency and efficacy between different search methods (Poetz & Prügl, 2010; Stockstrom et al., 2012; von Hippel et al., 2009).

Our own experience and discussions with several seasoned researchers and practitioners doing these searches suggest, however, that in reality there is also still an element of skill, intuition, and combination of different methods involved in conducting real life searches. It seems that unharnessed potential lies in integrating

[1] Lead users are users who face needs before the majority of the market and benefit significantly from obtaining solutions to those needs (von Hippel 1986; von Hippel 1988).

the increasing array of newer search methods and tools supporting the implementation of the methods. For instance, the gathering, accessing and structuring of information with various ICT-solutions is taking big leaps alongside technological development. In short, the efficiency and efficacy of searches is improved by seizing emerging opportune moments and by varying the search method in accordance with the contingencies of the given search.

In this paper we seek to elaborate some of the characteristics common to many rare subject search processes, their contingencies, and research tactics. We are hence suggesting that there is value in the skill and tactics that go into many de facto searches that combine different search methods. Building on the idea of lead-user pyramiding, we suggest performing an iterative and varying set of search forms, an approach we call mountaineering, to traverse towards the peak research subjects by treating the different search methods as a combinatory gear set.

This exposition holds value for three reasons. First, it is unhelpful for the proliferation of rare subject search methods if they remain presented only in an idealized linear and rationalized manner. We do not claim that one could not proceed by, say, screening or pyramiding alone, or claim that our combinatory approach would be necessarily superior. We contribute by showing how the job can be done with a more combinatory, iterative, and opportunistic approach. Future teams are likely to find themselves in search terrains that resemble those we conducted and can usefully learn from our experience. To aid this, the full search process depictions can be found in http://is.gd/mountaineering_review as animations. Second, the present article helps to elaborate the skill involved, makes visible the kind of contingencies, choices, and opportunities there are in rare subject searches, and how they are amenable to different search sequences and options. Third, skill elaboration and rigorous methods testing may offer complementarities. Rational design and engineering methods are today known to have been important for advances in these professions (Pahl & Beitz 1996; Ulrich & Eppinger 2008; Cross 2000), their application in practice is by necessity adaptive and skillful, and not all elements of design contingencies have been amenable to improvement by formalization (Jensen & Andreasen 2010; Schön 1983). We hence believe that rather than rendering rare subject search methods "less respectful", elaborating their practical aspects is key to opening the space for their further improvement.

We proceed by first recounting the established methods for the finding of rare subjects with small notes on accumulated experience. Thereafter, we introduce the idea of mountaineering and the four principal and two supportive case searches on user innovations in online teaching and learning and in renewable energy technologies. Discussion and conclusions follow.

# 2. Approaches to Rare Subject Identification

Literature to date has suggested the methods and directions that follow as a means to finding rare subjects for research and R&D. While all might work alone, a suitable combination is, we suggest, likely to be a powerful approach that has higher propensity to success than any one method alone.

## 2.1 Snowball and Pyramid Sampling

Forms of purposive sampling have long been used in social sciences to identify research subjects (Patton 2002; Flick 2009). Snowball sampling, which can be placed within the wider set of link-tracing methodologies[2] (Spreen, 1992, p 42), means that individuals are asked to identify people who have a desired characteristic (Goodman 1961; Welch 1975), or who can provide important information. Snowball sampling is most applicable in searches where characteristics are of a sensitive nature, in searches for elites (Peters & Waterman 1982; Kanter 1983), and when there are no available statistics – that is, the size of the population is unknown (Atkinson & Flint 2001). It has been used in studies of "hard-to-reach" or "hidden" populations such as prostitutes (McNamara 1994; Faugier 1995), drug users (Avico et al., 1988; Griffiths et al., 1993; Kaplan et al., 1987), pickpockets (Inciardi 1977), and aids sufferers (Pollak & Schiltz 1988).

Pyramid sampling (i.e. pyramiding) is a variant of snowball sampling, asking for nominations of individuals who know more or have more of the sought attribute (von Hippel et al. 2009). Pyramiding and other snowball strategies can be seen as a method of contact in a practical sense and as a method of sampling in a more formalized sense (Atkinson & Flint 2001). An additional merit of snowball and pyramid sampling is the possibility to refine questions during the sequential search, as the searchers learn more of the search domain and population at hand.

## 2.2 Screening

Screening, also known as complete enumeration (Gobo 2004) and saturation sampling (Spreen 1992), is an approach based on collecting information from every member of a population in order to identify the members with desired

[2] Link-tracing methodologies presume the existence of some kind of "linkage" or "bond" with other people in the sample population (Spreen 1992, 35).

attributes. Formerly, academic user innovation researchers have used screening of their questionnaire respondents as the dominant form of rare subject searches. Screening helps to obtain an overview of the entire population and variance within it, helping to differentiate lead users from the rest. It also offers excellent backwards compatibility to previous research, when utilizing lead-user survey and respondent self-assessment. However, the rare nature of the sought lead-user attributes can make screening inefficient when identifying lead users (Sudman 1985). The lead-user study of Lüthje (2000) provides us with an example. He reports screening 2043 persons to identify 22 lead users – a sampling efficiency of only 1.1 %.

Von Hippel et al. (2009) have tested the efficiency of pyramiding compared to screening in the search of lead users and found that pyramiding was more effective and suitable for their purposes. In their study of 663 pyramiding search chains in 18 settings, to which a screening approach was also applied, they found that the effort of pyramiding search is, on average, only 28.4 % of the effort of screening. Stockstrom et al. (2012) analyzed data collected from 940 pupils in 42 school classes, simulating a total of 13188 search chains. First, they found pyramiding to require, on average, 31 % of the effort of screening. Second, they found that the level of visibility of the focal search criterion is positively associated with the efficiency of pyramiding. They also found that the relative efficiency of pyramiding vs. screening increases with an increasing population size.

## 2.3 Broadcasting

Broadcasting means advertising the need for a solution or expertise in hope of relevant people self-selecting to respond to it. (Lakhani 2006; Jeppesen & Lakhani 2010) This approach is rooted in the view that innovations or drivers of change and progress often come from outside or from the margins of established research communities (Chubin 1976; Crane 1969; Edge & Mulkay 1974), so in order to increase the probability of a successful response, problems need to be broadcasted to a heterogeneous set of solvers not necessarily associated with the problem holders or their scientific and technical domains (Lakhani 2006). Compared to the methods above, broadcasting relies on the active role of participants, who self-nominate to participate.

A common form of broadcasting is to post a problem on an Internet discussion forum or a mailing list of a special interest group, although creativity in choosing channels may point to e.g. technology blogs (Droge et al. 2010), or a paid ad in a relevant magazine or social media, such as Facebook. Broadcasting has been combined with pyramiding in several lead-user projects (e.g. Hienerth et al., 2007).

## 2.4 Other Sampling Methods

Often the population is too large to be screened, so a sample must be drawn. There are numerous sampling strategies available in the literature, such as a sample of extreme situations in order to maximize variation, quota sampling for objects that contain a wide range of statuses, emblematic sampling (Gobo 2004), location sampling (e.g. Kalton, 2009; Sudman, 1980), random sampling (e.g. Lohr 2009), and samples targeting typical or critical cases (e.g. Patton 2002), or anomalies.

In some lead-user studies, researchers have gained or sought access to user communities, for instance in mountain biking and kayaking, which has provided pointers to prominent lead users (Hienerth, 2006; Lüthje et al., 2005). While this works for several types of products and users, we suggest below that e.g. large online user forums can be effective places in tracing user innovations and innovating users behind them (Freeman 2007). "Netnography" in user forums is a recently emerged method for analyzing online communities systematically (Kozinets 1998; Kozinets 2010). It was applied successfully by Belz and Baumbach (2010) to identify lead users. In practice, netnography means, in fact, using a combination of purposive sampling methods in the targeted user forum.

Often a practical starting point for familiarizing oneself with the field where rare subjects are to be searched involves systematic and/or opportunistic sampling of various media sources such as journals or newspapers. It can, for example, take a form of an extensive literature review, utilizing online search engines or following feeds from social media applications. Retrieving information from databases and using online search engines such as Google also belong under the umbrella of sampling.

## 2.5 Investigating User Solutions and Investments

In some cases, snowball and pyramid sampling provides leads that do not refer to particular persons, but to working solutions for a related problem or need. Many lead users have developed prototypes, modifications, or other iterations of existing products to meet their needs, which the products on the market do not yet satisfy (Baldwin et al., 2006; von Hippel, 1976, 1988). These user solutions and investments can be investigated by, for instance, running software demonstrations, trying out solutions or having experts evaluate them, or simply assessing the peer commentary about the solution. Investigating user solutions is an adequate strategy in lead-user searches, since lead users are more likely to have built such solutions than other users (Bilgram et al. 2008; Skiba & Herstatt 2009; Jeppesen & Frederiksen 2006). We also report below how it makes sense to ask where innovating users have gained the ingredients for their innovation, that is on whom or what have they built upon in their innovation.

## 2.6 Miscellaneous Encounters

Miscellaneous and informal encounters, such as casual coffee table discussions, can provide leads for more systematic searches. These encounters refer to situations where the researcher has found a lead by being in the right place in the right time, but the main activity has been something other than systematic searching. One can also spot a relevant lead for a rare subject while browsing through an online newspaper, for example.

## 2.7 Summary

In summary, there is an increasing array of promising methods to find rare-research subjects, lead users in particular. They have varying strengths and weaknesses that are relatively hard to assess from the onset of a new lead-user search process. It is not a coincidence that many lead-user projects have opportunistically used a bit of this and a bit of that approach to accomplish their searches, even if they primarily relied on one of the above methods.

# 3. The Idea of Mountaineering

The basic metaphor of pyramiding is finding one's steps up a pyramid to reach to the top lead user(s). Mountaineering is similarly a way of "traversing upwards" towards those people, who have the sought-after characteristics (lead userness in case of lead users), but not through just pyramiding, but with a suite of means from which one can select the most appropriate to the situation at hand (Figure 1).

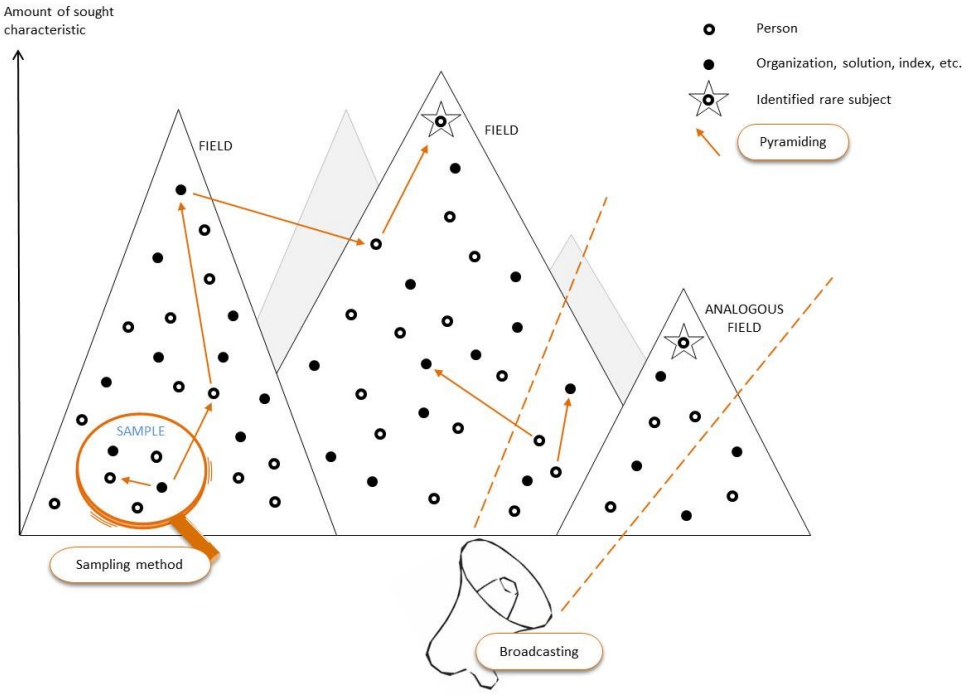


Figure 1. The idea of mountaineering: "traversing upwards" towards those persons or intermediary leads who have the sought characteristics, with a suite of means from which one can select the most appropriate to the situation at hand.

The mountaineering approach to rare subject searches means that the search can be started with many given starting points and methods, making iterative changes in search strategy as the quest proceeds. As with any search for a maximum, local maximums tend to emerge, and if the target is to find the top or close to the top people with regard to sought-after characteristics, these need to be somehow discerned and surpassed (a "lower peak" problem). In case of lead-user search, it must be noted that the current user population of the product or service in question does not bound the search.

In the process of mountaineering one moves step by step from a lead[3] to another. People are relatively easy leads to approach as most contact information is fairly easy to find, for example phone number and email details. Sometimes the suggested leads include organizations, events, locations, user solutions, analogous fields, or online discussion forums. These leads need to be approached, investigated or sampled to reveal the persons behind them. Table 1 lists the mountaineering lead types and methods.

Table 1. Lead types and applicable methods

| LEAD TYPES | METHODS |
|---|---|
| **Person**<br>An individual with a name | Snowball and pyramid sampling |
| **Organization**<br>Formal organization (e.g. company, agency, non-profit, school) | Screening,<br>Broadcasting,<br>Other sampling methods,<br>Investigating user solutions and investments,<br>Miscellaneous encounters |
| **Event**<br>Conference, seminar, fair, etc. | |
| **Location**<br>Meeting place where people hang out | |
| **Media**<br>Mass-media (newspaper, TV, radio, company website) excluding CMC (below) | |
| **Computer-Mediated Communication (CMC)**<br>Interactive computer media (e.g. blog, forum, wiki, mailing list, social networking site, chat, online community) | |
| **Solution**<br>User innovations, prototypes, etc. | |
| **Field**<br>Professional field or domain (e.g. superconductors, banking, public health care) | |
| **Index**<br>Searchable index of things, people and their personal information (e.g. census, health care records, tax records, databases, search engines) | |
| **Personal network**<br>Personal network of the person conducting the search (e.g. colleagues, friends, family) | |

Because people's relations in society are both direct and indirect, Table 1 also includes intermediary lead types, such as organizations, locations, and various media, which highlights the role of collective, geographic, and material actors in finding lead users. This list is not exhaustive of all conceivable actors in society, but these non-overlapping lead types stem from both lead-user literature and encountered leads in the cases of this study, which have distinct points of contact. A formal organization has a contact person, one can participate in an event, go to a location, read media, register on an online discussion forum, demonstrate or try out a user solution, grab a reference book for a professional field, search an index,

[3] A lead here means an indication or a clue of where to go next in the process of mountaineering. Not to be confused with lead user, where 'lead' refers to leading the market (see footnote 1).

etc. The personal network is included to show that the researcher sometimes can draw mountaineering starting points from their own membership groups.

The notion of field refers to analogous fields outside the target market, as presented in the lead-user literature. For example, the anti-lock breaking system (ABS) was an innovation made in the field of aerospace. Today, the system is used in standard cars around the globe (von Hippel et al. 1999). Poetz and Prügl (2010) addressed the potential of pyramiding for crossing domain-specific boundaries by analyzing 1147 interviews conducted in the course of pyramiding search processes in eight lead-user studies. In their study more than one third of those interviewees who were able to provide a valid referral in their interview, could refer to one or more analogous domains previously unknown to the searcher.[4]

One of the core skills is to know which means are appropriate to carry to each user domain and search interest, but these choices are less radical than in committing to just one search method. Training corporate people or other non-social scientists effectively in all possible methods and method selection may not be feasible, and expertise is needed at least in determining which means are likely to be most suited for the task and domain at hand.

[4] The interviewees' levels of expertise as well as their domain origins influence the likelihood of a domain-crossing referral. Also, the type of industry in which the search field is located is found to moderate the effect of expertise on the likelihood of a referral into an analogous domain. (Poetz & Prügl 2010)

# 4. Elaborating Mountaineering through Real Life Cases

## 4.1 Data and Methods

Below we report four principal and two supportive lead-user and user invention searches conducted in Finland during the years 2009–2012 by our six-person team using the mountaineering search strategy in basic and applied research projects. All of the interviews conducted have been transcribed and lead userness has been assessed with self-assessment questions drawing on Franke et al. (2006), using a similar operationalization of lead-user characteristics. Lead userness was measured by four seven-point Likert-scale questions; the scores were totaled without weighting, leading to a maximum rating of 28. The form of the questions was retained, while the content reference was changed from the original kite surfing context to the searches at hand, e.g. heating equipment (Appendix A). We hence followed Stockstrom et al. (2012) and their lead-user identification process in a school context.

Table 2 presents the cases and their characteristics. The four principal cases are presented in detail in the following section; the first two relying more on parallel search strategies among different networks and the latter two based more on investigating user forums. The supportive cases are very similar to the wood pellet searches, and are described together below.

In the diagrams below[5], which graphically document the actual search processes, the horizontal axis represents time from left to right in relative terms, not as an absolute scale. The vertical axis represents lead userness, that is, the sum of the self-assessment score. The lead userness of those users whose inventions were identified in forums but who did not respond to our contact requests, were rated with the aid of three domain expert evaluators, who also rated the innovativeness of the user-developed concept. A lead that is not yet investigated is represented by a smaller circle, positioned close to the actor providing the lead, and is transformed into a bigger circle at the time of contact. Starting points for searches are placed close to the bottom of the vertical axes, since the starting points do not have a lead userness score. Appendix B contains legends for the diagrams. With regard to positioning of the circles in the graphs, while persons have been given a lead userness rating (i.e., clear y-axis position), the positioning of other

[5] The full search process depictions can be found in *http://is.gd/mountaineering_review* as animations.

circle types depend on nearby circles, as well as default values of the force-directed graph library. Where lines, labels, or circles would have become otherwise unreadable due to clutter, minor manual adjustments were made.

Table 2. Case comparison

| | | Principal cases | | | | *Supportive cases* | |
|---|---|---|---|---|---|---|---|
| | | Web Service for Teachers | Solar Panels | Wood Pellets | Solar Thermal Collectors | *Ground Heat Pumps* | *Air Heat Pumps* |
| Facts | Consumer good | no | yes | yes | yes | *yes* | *yes* |
| | High tech | no | yes | no | no | *yes* | *yes* |
| | User population[6] | 65 000 | 50 000 | 25 000 | 10 000 | *70 000* | *440 000* |
| | Well-defined domain | no | yes | yes | yes | *yes* | *yes* |
| | Public visibility of user activities | high | med | med | med | *med* | *med* |
| | Large online forum | no | no | yes | no | *yes* | *yes* |
| Project | Commissioned | yes | no | no | no | *no* | *no* |
| | Aim was to identify | 5 workshop participants | 5 workshop participants | as many lead users and user inventions as possible | as many lead users and user inventions as possible | *as many lead users and user inventions as possible* | *as many lead users and user inventions as possible* |
| | Multiple researchers | yes | no | no | no | *yes* | *yes* |
| | Tight schedule | yes | no | no | no | *no* | *no* |

## 4.2 Case Web Service for Teachers

**Project context.** Finland's national public service broadcasting company (Yle) needed to redesign its web service for teachers, Opettaja.tv ("Teachers' TV"). The goal was to experiment on a new integrative and iterative search process in order to find five lead users representing different areas of the service to take part in a workshop. The service was open to everyone, although clearly aimed for teachers of elementary and secondary education who number approximately 65000 in Finland.

**Process.** We used a range of sources to familiarize ourselves with the service and domain, and then ran two workshops with users and designers to refine the search goals.[7] The initial starting points were acquired by various sampling strategies such

[6] Current user population of the product or service class in question. NB: Lead-user search is not limited to this population.

[7] Pyramiding requires a place to start, screening requires a sample, and broadcasting requires a direction. As the case was to improve the existing design of the current web service, it was important to include the redesign relevant areas of the service. In addition to acquainting to the service, a method (Helminen et al., 2010) was created for capturing the perception of different stakeholders – designers and users of Opettaja.tv web service in this case.

as media scanning, Internet search and miscellaneous means, and included personal contacts, workshop participants, project partners at Yle, and newspapers (Figure 2). Miscellaneous sources for new starting points were not neglected at any point of the process.

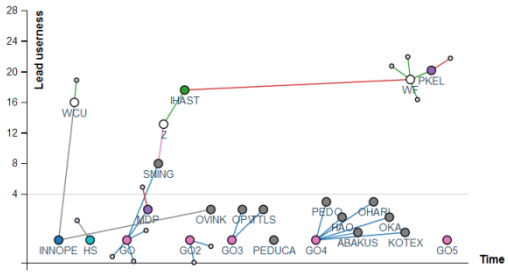


Figure 2. First stage of the web service lead-user search and the longest chain taking shape: Sampling (on Google GO), broadcasting (in an online community SNING), pyramiding (from a person Z), investigating user solutions (inside an organization IHAST), pyramiding (from a person WF), and finally investigating user solutions (person behind a solution PKEL). The person at the end of the chain was later confirmed to be a lead user. The lower section shows the multitude of leads from early familiarizing of which several would later be used as a place for broadcasting. Circle types and colors are listed in Appendix B.

After the first stage, the search was characterized by our pyramiding efforts beginning to hit users that had made their own inventions or were otherwise very knowledgeable of the teaching media domain (lead-use experts). Some of these people provided extensive lists of further leads and the team had to concentrate on choosing, which leads to follow. In Figure 3 this is visible in the great number of leads that still remained un-followed at the end of the process. The selection of leads to follow was based on how promising the leads appeared to be for the researchers and whether they would help in covering all the relevant development areas of the service. Pyramiding continued until the final stages of the process, broadcasting still running at the background, and late in the process we found one more starting point that eventually led to a lead user.

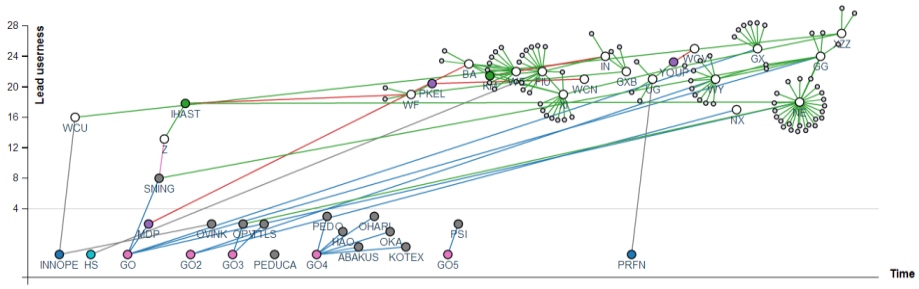


Figure 3. Final stage of the web service lead-user search: Pyramiding further with broadcasting still on the background. A late new starting point (PRFN) led to a lead user.

In all, the search resulted in 19 contacted persons and 96 other identified leads such as solutions, best practices, and non-contacted persons. Eventually 5 lead users representing different areas of the service were identified and selected for a lead-user workshop. Many of the leads were deemed unnecessary to follow up on because of their irrelevance. Several leads were either commercial or open established solutions and many were also bypassed due the budget and time constraints as the required 5 "lead user enough" persons were found in relevant areas of the web service. As von Hippel et al. (2009, 1403) state: "In real life searches it is almost always the case that one does not necessarily need to reach the 'top of the pyramid' in order to get an appropriate solution." The workshop results and insights gained during the process were condensed into a new concept of Opettaja.tv web service, which was considered thrilling and warmly welcomed at Yle. Its uptake and implementation is ongoing.

**Case highlights.** This case demonstrates the following strengths of the integrated mountaineering approach: multiple parallel search strategies, adapting to the situation, and continuous starting points. The longest chain, taking shape in Figure 2 and completing in Figure 3, contains several changes of methods and various sources of new search directions elaborating the necessity of quickly aligning the approach to the situation at hand. Another issue to consider is the new starting point discovered late in the process that led to a lead user. Should we have neglected new sources after the initial phase, we probably would have missed this innovator, who was identified behind a superior solution. This type of pattern of discovery took place several times – innovating persons were found behind solutions and organizations. Moreover, some of the advanced social media solutions were found from analogous fields. In the case, we additionally consciously aimed for such fields, even though it is also typical to end up there by accident – a phenomenon linked especially to the use of pyramiding.

**Lead-user example.** A high school mathematics teacher who has, for years, uploaded short self-made "how-to" video clips on Youtube to help his own pupils do their homework; at the time a rare and new activity.

## 4.3 Case Solar Panels

**Project context.** The solar panels (photovoltaics) search was designed to become comparable with the web service case through having a specific business target, five relevant trends, and a technology domain that does not feature a large national Internet user forum (see cases below). Solar cell technologies is a high-tech domain unlikely to be accessible to user innovators, yet a working installation is much more than solar panels: mounting angle, location, and structure, as well as

electrical power infrastructure[8]. Most solar panel installations in Finland are off-grid, and a cautious estimate would be that there are around 50 000 installations, mostly in summer cottages.

**Process.** The search process started with leads from knowledgeable colleagues, including the solar electricity discussion section of ilmaisenergia.info Internet forum (identified in the supporting solar thermal case, see below). Thirty-two discussion threads with 636 messages and sporadic discussions concerning a handful of DIY-projects were found, of which the most leading edge user had already been identified and interviewed in the solar thermal case. In the solar panel case, the Internet forums did not contain many posts or user inventions compared to the wood pellet and solar thermal cases below, so the researcher continued gathering starting points, which included participating in two professional development events on solar energy. Figure 4 illustrates the early phase of this case.

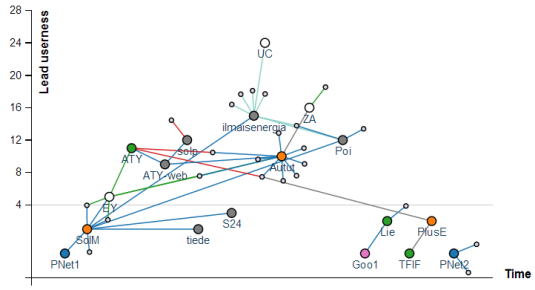


Figure 4. First stage of the solar panel mountaineering: As forums did not yield enough leads, new starting points were sought.

The next steps included interviews with the two most referred leads (ZJ and PA), which were key intermediators in the solar business network, but it turned out they had no further contact with relevant solar panel lead users, and neither did the two other interviewed solar business leads (CR and EE, see Figure 5). However, one of the professional development events pointed to a lead-use expert, who was able to turn us to a lead user. Thus, in this case the results of the mountaineering business network leads included not only one lead user, but also dead-ends (see Figure 5).

[8] Current regulators, DC/AC current inverter, cables, and possibly batteries to store electricity, as well as reserve power generators.

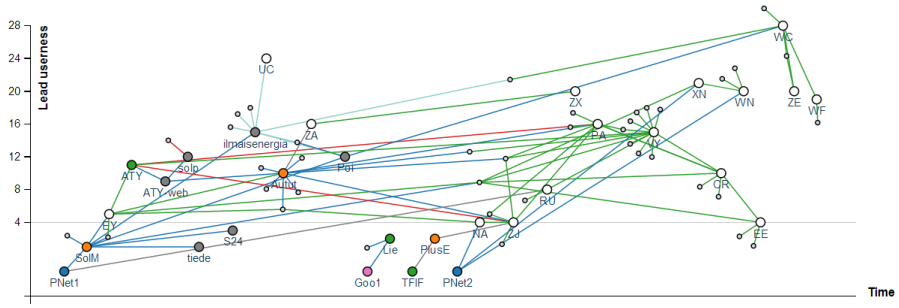


Figure 5. Final stage of the solar panel mountaineering: With the help of new starting points and new messages on the previously followed forum, the search accelerated and lead users were found.

Discussions with engineer friends revealed two other lead users. This demonstrates the significance of the personal networks. Some time into the search, a user, who was in the middle of figuring out solar tracking, posted new messages on the forum. As that user turned out to be a lead user, the goal of finding five lead users or lead-use experts was met and the search ended. Although there were no large solar panel online forums available, even the small number of posts led to identifying two lead users.

In all, the solar panels search resulted in 15 contacted persons, among which 5 lead users representing relevant trends were identified.

**Case highlights.** This case demonstrated a mix of personal networks, business networks, and online methods to identify lead users. Since solar panel technology is very high-tech and had low public visibility in Finland, starting points were scarce. The researcher took part in business events to learn about the technology, related trends, and leads. Most central actors in the business network were domain experts, as expected, but these did not know any lead users.

**Lead-user example.** A building engineer, who was disappointed with the market offering at the time, decided to import solar panel system components himself, in order to achieve lower costs and improved materials suited for the humidity of the Finnish Archipelago. The successful solving of importing and installation problems for his summer cottage led him to start a business in the domain.

## 4.4 Case Wood Pellets (supported by Heat Pump cases)

**Project context.** This case is part of a research project to identify and analyze user inventions in renewable home heating systems. The goal was to find as many as possible lead users and user inventions in wood burning pellets, ground heat pumps, and air heat pumps in Finland. We found in total 192 inventions, which domain experts verified (Hyysalo et al. 2013a; 2013b). All of these three technologies and the modifications done to them are actively discussed in large national Internet forums, which affected strongly what kinds of search sequences

were sensible. As these three cases very much resemble each other we describe here only the wood pellet search in detail.

**Process.** Having conducted two searches on heat pumps that benefited from screening Internet discussion forums, we again first scanned the web for forums relating to wood pellets and found a large active forum pellettikeskustelu.net, which had 1897 registered members featuring 46830 posts in 3194 threads and 'own inventions/constructions' section comprising 1635 messages in 123 threads. The totality of messages in the section was screened for user inventions and the effort provided us with potential and confirmed lead users visible in Figure 6. Alongside, we carried out simultaneous pyramiding by starting with 10 interview requests through the website. The names coming up in the interviews were, however, also found through screening, partly because the forum also revealed indigenous pyramiding within, as the forum posts internally referenced leading users to other people.

In the course of the study we sent 20 more interview requests. Only 13 out of the total of 30 responded and agreed to be interviewed. These interviews led to 4 new suggestions of lead users on the forum, of which two agreed to be interviewed but gave no further references thus ending this line of inquiry. The interviewees pointed us to specific sections in the forum, which were already identified earlier when screening the forum but left out of scope. It was only after these second referrals from the two interviewees that these sections were screened (see Figure 6). This led to one already identified lead user and three further potentials that did not respond.

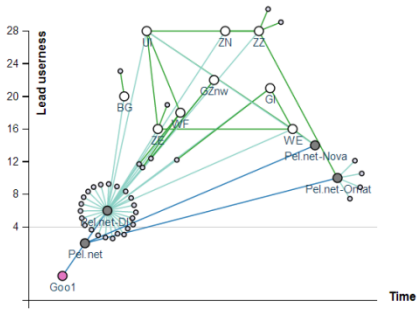


Figure 6. Early stage of the wood pellet lead-user search: Forum screening reveals more lead users that become confirmed in the course of pyramiding interviews and two new forum sections (the rightmost circles) are screened only after second referrals.

In addition we used 5 other reference points external to the forum. Our Google searches conducted in the very late stage still revealed one lead user (WYn). The leading national newspaper 'Helsingin Sanomat' (HS) featured an article about a DIY pellet burner project, the maker of which did not respond to our interview request. Another research project "eco-forerunners" featured a user-

manufacturer, who then pointed to two further subjects, of which one turned out to be a domain expert and the other deceased (Figure 7).

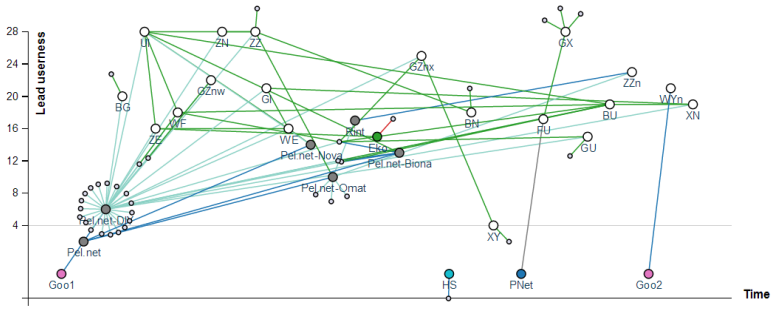


Figure 7. Final stages of wood pellet lead-user search: Forum screening reveals still more lead users, new forum section, and five more starting points (forum leads reduced in the illustration).

In all, the wood pellet search resulted in 18 contacted persons, which included 10 people who had the score of 20 or more in the lead-user self-assessment. In total these searches revealed 67 inventive user projects and confidence that we had covered most of these activities in the Finnish context.

**Case highlights.** Wood pellet and heat pump user innovation searches exceeded our expectations in that we were able to identify a greater number and variety of user inventiveness than we expected. User forums appear to present a promising environment for rare subject searches, particularly if the aim is to cover the area. However content analysis of posts takes a lot of time and may not be feasible in commercial projects. Forum activity and other "netnography" methods can lead to lead users, but not necessarily. For instance, in ground source heat pumps the inventive users had only a moderate level of postings and details revealing them required reading into the threads in detail. Second, pyramiding is greatly hampered by slow response times and receiving no responses – we experienced lags of weeks and months. This calls to question attempts at optimizing pyramiding by just opting for the most promising subject and discarding other routes. Third, events taking place after the initial effort played a notable role: second referrals led to decisions to screen originally bypassed forum sections and a Google search in the very late stage still revealed one lead user. The combination of search methods and use of multiple starting points thus also appears a feasible strategy in the presence of large Internet forums particularly if one needs to perform the search quickly.

**Lead-user example.** A metal technician-plumber-IT person develops a novel pellet transfer system because there is no commercial product available. It was also cheaper to do-it-himself from what comprised of mostly recycled materials. His pellet transfer system draws pellets from a larger area than a spiral conveyer, and digs down to the bottom of the pellet silo thus preventing pellets from arching and

ash from accumulating. He produces and sells the system “Pellet Elephant” to other forum members (so far 100 pieces) for a minimal mail delivery fee.

## 4.5 Case Solar Thermal Collectors

**Project context.** This case is also part of the renewable home heating systems project, now moving to solar thermal collectors. The goal was to find as many as possible lead users and user inventions in Finland.

**Process.** In this case the search differed significantly with regard to how and how much forums could be used in mountaineering. Our first starting point was an offshoot from pyramiding in the earlier heat pump study: a lead user pointed us to a smaller renewable energy forum (ilmaisenergia.info) that also covered solar thermal collectors. The forum was used for screening a potential solar thermal collector, photovoltaic solar, and wind energy lead users and user inventions. Our second starting point was the energy section at Tiede magazine’s (a Finnish science magazine) Internet forum. The solar thermal collector specific discussion at ilmaisenergia.info and at tiede.fi was relatively limited and screening resulted in 13 and 3 potential contact points respectively in these two forums (Figure 8). We also already knew one lead-user contact given by a lead-use expert and our earlier renewables searches had already pointed to another lead user in solar collectors.

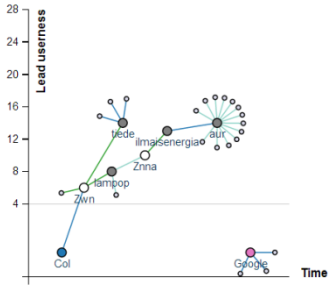


Figure 8. The first stage of solar thermal lead-user search: Screening on forums revealed few potential lead users.

We also carried out Internet searches to find users with blogs, resulting in 3 names. Altogether we had 21 potential lead-user names, which already included 2 persons that were interviewed in earlier renewable energy studies. Interview invitations went to 19 persons. Eleven gave a positive response and were interviewed. We used further pyramiding and snowball sampling in these 11 interviews, leading to 15 new contacts and 3 previously recognized names. (In addition, the interviewees recommended 3 companies to be interviewed). However, of these 15 new pyramiding leads, only two users accepted our interview request. The new leads obtained in these interviews led only to already known contact points. At this point (Figure 9) we could have moved back to screening or

broadcasting to find more users, but the data set gathered thus far appeared sufficient for the research questions posed with regard to user inventions in solar collectors.

In all, the solar thermal collector search resulted in 19 contacted persons, which included 9 who had the score of 20 or more in the lead-user self-assessment.

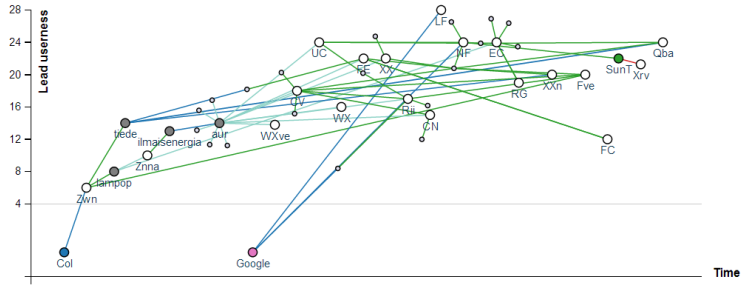


Figure 9. Final stage of solar thermal lead-user search: Internet search, pyramiding and snowball sampling have saturated.

**Case highlights.** The mountaineering search relating to solar collectors indicates how this type of search process increasingly shows its strength when one or the other of the methods is not clearly superior for the purpose at hand. The multiple starting points helped to make a fast and efficient study despite the facts that none of the forums or the other user communities concentrated on inventive users, and that there were no means to delineate effectively a population to which e.g. a lead-user survey could have been sent.

**Lead-user example.** An engineer in a Finnish company producing fuel supply systems for large ships developed a hybrid heating system wherein a solar thermal collector was combined with a ground source heat pump. In the summer, when the hot water tank is fully heated, over-production of solar heat is directed to the ground source heat pump well. The bedrock temperature rises, which can be utilized for winter heating with greater heat pump efficiency. In addition to the winter benefits in energy efficiency, the invention addresses the summer time overheating problems of solar thermal collectors.

## 4.6 Summary of cases

Table 3 below presents key statistics on the search process for the cases. For instance, the number of leads suggested during the whole search process and how many people were contacted. The iterative nature of the mountaineering approach is visible in the number of starting points. The variance in method usage is visible in the row “different methods” and the more detailed variation of all used methods, starting points, and identified leads is presented in Appendix C.

Table 3. Summary of cases and characteristics of searches for finding 5 lead users in each case.

| | **Web Service for Teachers** | **Solar Panels** | **Wood Pellets** | **Solar Thermal Collectors** |
|---|---|---|---|---|
| **All** | | | | |
| Leads | 115 | 66 | 61 | 43 |
| Contacted persons | 19 | 15 | 18 | 19 |
| Starting points | 9 | 4 | 4 | 2 |
| Different methods | 5 | 5 | 5 | 4 |
| **Top 5** | | | | |
| Total steps | 3+1+3+7+2 | 3+8+1+1+5 | 3+3+5+3+2 | 6+1+1+3+3 |
| Second referral | 2 | 2 | 1 | 0 |
| Case highlight | Multiple starting points | Personal network | Internet Forum | Shifts between search methods |

The term "Top 5" refers to the parts of the search process leading to top-5 lead users, which we chose as an additional comparison frame between the cases. It entails the total number of steps from the starting point to finding the top-5 lead users. The row titled "second referral" refers to how many of the five paths to lead users include diverging and converging chains. For instance, sometimes the same lead is suggested more than once by different people, which gives more importance to that lead, suggesting it to be an obvious next step (see Figure 10).

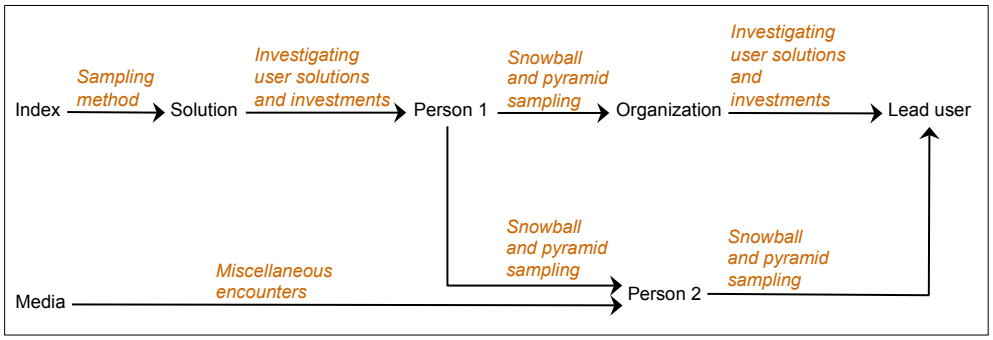


Figure 10. Example search chain that diverges and converges. Person 2 is contacted only after the second referral.

# 5. Discussion and Conclusions

Mountaineering is an opportunistic search strategy that differs substantially from the linear schematic depictions given of lead-user search methods as well as modeling and optimization of individual methods such as screening and pyramiding. We argue that this difference is the strength of this paper for three reasons. It brings us closer to the reality of many actual lead-user searches, elaborates the skills involved, and also provides new insight on what constitutes effort and efficiency of a search method, thus contributing to sharpening future comparisons of e.g. pyramiding and screening.

Let us start with the reality of lead-user searches. In all our cases we used a combination of methods to identify lead users. The most effective search method appears to vary significantly from case to another as well as with regard to the phase of the particular case. For instance, the mix of a domain expert-broadcast-pyramiding search strategy used in the web service case would have been less efficient in the heat pump and wood pellet searches compared to the now opportunistically used large Internet forums. The renewables searches – solar panel, wood pellet (and heat pump), and solar thermal collector cases – further show that the details of the effective search strategy can vary even between neighboring technologies and with different search aims. In general, forums can be immensely useful, but screening them is very time-consuming and thus not recommended without a tailored sampling strategy that targets the sweet spots for the information and people searched for.[9] Screening is very effective whenever there is a self-nominated subsection of a user population, such as in our cases of wood pellets and heat pumps.

Pyramiding (or networking) as a method for lead-user identification is described in the literature as chains between individuals (e.g. Churchill et al. 2009; Hienerth et al. 2007; Lüthje & Herstatt 2004; Stockstrom et al. 2012). In our cases, we quickly noticed that intermediary leads often link people. We learned that instead of asking for referrals from individuals, we should ask where to look for more information. Many contacted persons knew about leading-edge forums or organizations, and some could pinpoint a user-generated solution without knowing anything about the person behind it. The type of lead also defines what methods can be applied next. Only individuals can be asked questions – all other leads must be investigated in a different manner (see Table 1). It can also be difficult to decide

[9] Our experience has made us skeptical of solely relying on mechanistic netnography such as present day forum statistics, search functions, or crawlers in uncovering user inventions.

where to begin the pyramiding search. Our cases present actual pyramiding trails that are hopefully of help for the next person starting their lead-user identification process.

The downside to relying on link-tracing strategies, such as pyramiding, with few starting points is that 'isolates' who are not connected to any network run the risk of being missed (Atkinson & Flint 2001; van Meter 1990). For this reason, we used multiple starting points in our searches. Figure 3 relating to the web service search and Figure 7 to the wood pellet search show a lead user being found very late in the process and not connected to the initial chains.

Discussion similar to this has recently emerged in the field of human–computer interaction – a field where the debate on choosing the "best" method for some specified context has prevailed for the past decades. Woolrych et al. (2011) argue that only very few comparative research studies investigate methods as they are used in practice: as combinations of methods and their components.

Our second line of argument is that skill can be elaborated. Even if the "bad news" is that lead-user searches may be messier and require greater skill than usually portrayed, the good news is that this part of the skills can also be elaborated. Our own learning sequence in conducting six mountaineering searches suggests the following rules of thumb for conducting the searches.

- Using an array of different starting points from the outset helps to cast your nets widely and diversely.
- Broadcasting early and whenever new potential broadcast media or community becomes salient makes sense: the effort is small but answers take time. On the other hand, the further you are in the search process, the better you are able to format the content of your broadcasts.
- "Plunge in" as soon as you can rather than spend months on background work – the search itself is an excellent educator with regard to the domain, what to search for, and where inventive users may be found.
- Internet forums, particularly large ones, are excellent for starting, learning and screening for user inventions. However, if they are huge, the effort of screening is considerable and pyramiding, for example from the person with the most or most popular posts, could be considered an option.
- Work in parallel with different methods. Any single method can be effective but it is difficult to estimate how fast the progress will be or what possibilities are bypassed when relying on just one.

- Develop a well-elaborated interview routine, with precise questions for lead userness self-assessment, and a battery of questions for digging out the history of the inventions.

- During e.g. a pyramiding search, self and evaluator assessments can be tricky to deploy and adding proxy questions such "whose example did you follow, or where did you find your model?" became useful in revealing what was the inventive part.[10] Similarly, in screening an Internet forum, user self-assessment could not be used, but forums provided objective evidence of a person's competence and needs with the technology, and hence researchers can often soon begin to make fairly objective assessment to complement mere self-assessment. In research cases we used domain expert evaluators to verify our assessments at the end, but this can seldom be done in the middle of the search.

- Iterate trend definitions as the search matures. In all cases the user innovations and user innovators found sharpened the assessment of what were the relevant trends.

- Learn and iterate continuously. What the problem is, where to look for solutions, what analogies and areas of crosspollination there may be, how to formulate your questions and where to target your searches.

- Use a survey only if you know what your relevant population is and where and how to access it.

- If you take the effort, make the most out of it. In addition to lead users, user innovations, and trends, also different types of persons, such as intermediaries, experts, gatekeepers as well as for example, needs, or weak signals, may provide valuable input in different stages of a development and research processes.

Elaborating the mountaineering search process helps in the education of practitioners. The current linear and schematic portrayals of lead-user searches may be easier to communicate to customers and academic evaluation bodies, but they leave new practitioners with the full burden of learning how to apply them, and at worst how to deviate from them to get through the search process.

[10] For instance, one user had built a shed-like mounting structure on the ground for his solar panels and pointed to a German blog for inspiration and the reserve power for his installation, a wood gas burner, being partly copied from a book on the topic, which in turn, we could compare to his.

A big question in the multiple method approach is when to change from one search method to another. We took pains to try to find some universal rules from our data set, but have to conclude that the straightforward answer is opportunism combined with common sense, because the sensible moves varied so greatly with context and the phase of the search. In our searches, the method was changed or halted because

a) the existing method was not delivering or was slow to deliver (e.g., a pyramiding request to an anonymous forum user took time to yield an answer, screening was pursued in the meantime, occasional web site crashes in user innovation forums)
b) new opportunities arose (e.g., we found a forum or media where to broadcast)
c) there was time to work with parallel tracks (clock time being more important than absolute efficiency of time spent on search)
d) some leads appeared better than others that competed for time
e) certain lead types required a certain method in order to be able to proceed.

Our third argument concerns future research and the attempts to systematize pyramiding searches. Here our mountaineering searches offer complementary insight that may be worth taking into account. In simulations of screening and pyramiding (von Hippel et al. 2009; Stockstrom et al. 2012), the measure of efficiency has been the chain length, i.e. the shortest path from a starting point to the lead user. Our data, however, questions whether shortest path/chain length is a valid measure for method efficiency for the following reasons. We learned that even a long chain does not necessarily require a lot of effort in cases in which people are precise in their referrals and contact points to leads are easily found. Similarly some short chains became laborious, when one needed to spend a lot of time per lead searching for something to grab on to, for instance in vast online forums. Chains are also not always linear single chains but can diverge or converge (see Figure 10). When different chains yield different leads and resources do not allow for following all of them, it is often the second referral (i.e. the merge of two chains) that makes the lead stand out. In social network analysis terms: a lead with plentiful referrals has higher centrality compared to other leads. Many lead chains were also effectively blocked in many cases as many potential interviewees did not respond or responded after weeks or months delay. Thus, in addition to chain length, we argue that effort must include all steps taken to find a lead. Furthermore, after a lead user has been identified, subsequent referrals do not count as effort, even though they increase that lead's centrality. Simulations of lead-user searches often rely on complete information of a social network, which cannot be obtained in most real life searches. Results from lead-user simulations are in favor of

pyramiding, but as we encountered in the case of wood pellets, screening can be an efficient choice once a suitable population (such as an online discussion forum) is found.

A more open exploration pursued in this paper can benefit from refined pyramiding knowledge through, e.g., deciding when to pursue or refrain from pyramiding. Likewise, further simulations could, for example, explore optimal points to shift from screening to pyramiding, or criteria for alternative leads to pursue given the (usually less than optimal) kind and quantity of information available. Within mountaineering searches the following are obvious tracks of further research.

- Comparative studies between several groups doing the same real life search: e.g. one using screening, one pyramiding, one mountaineering. Recording both efficiency (time and resources spent) and calendar time (the time elapsed).

- Comparing the outcomes of method choice moments: one investigator pursuing one method, the other another. Compare the ensuing chains and outcomes.

To conclude, in the light of the six cases conducted, our more iterative and combinatory approach for searching rare subjects that we call mountaineering appears promising in taking us relatively quickly to both user-generated inventions and modifications, as well as to relatively knowledgeable lead users who have been instrumental in further pyramiding. Thus, at least in some domains and for some purposes, these means for lead-user identification offer useful compatibilities, which can be opportunistically exploited to make lead-user search more effective. This integration, in turn, offers fertile ground for further research.

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# Appendix A

**Self-assessment questions used, example from the Solar thermal collector case**

These questions follow the operationalization of lead-user characteristics by Franke et al. (2006) and Stockstrom et al. (2012). Franke et al. developed a set of questions for each lead-user characteristic, from which Stockstrom et al. selected the question with the highest Item-to-Total correlation. While Franke et al. measured the "Ahead of trend" construct with a Thurstone scale, Stockstrom et al. used another Likert-scale question, and we followed the latter (Table 4).

Table 4. Lead userness questions, measured on a seven-point Likert scale.

| Lead-User Characteristics | Question |
|---|---|
| Ahead of a Trend | I have improved heating equipment on my own. |
| Technical Expertise | I can make technical changes to my heating equipment on my own. |
| High Benefit Expected | I have already had problems with my heating equipment that could not be solved with the manufacturer's conventional offerings. |
| Community-Based Resources | I know many other people who optimize heating equipment and have a thorough knowledge of heating equipment. |

# Appendix B

**Legends for the graphs used in this paper**

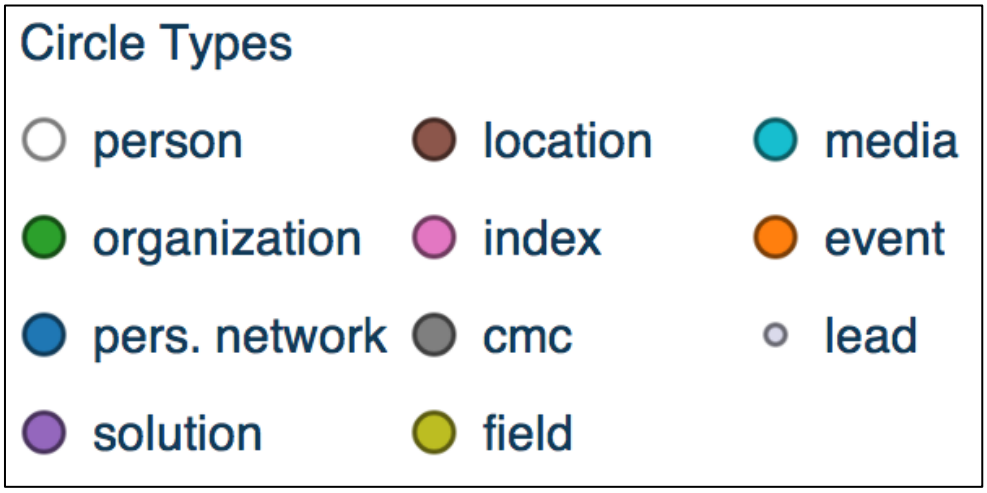


Figure 11. Circle types in the graphs, elaborated in section “The Idea of Mountaineering”.

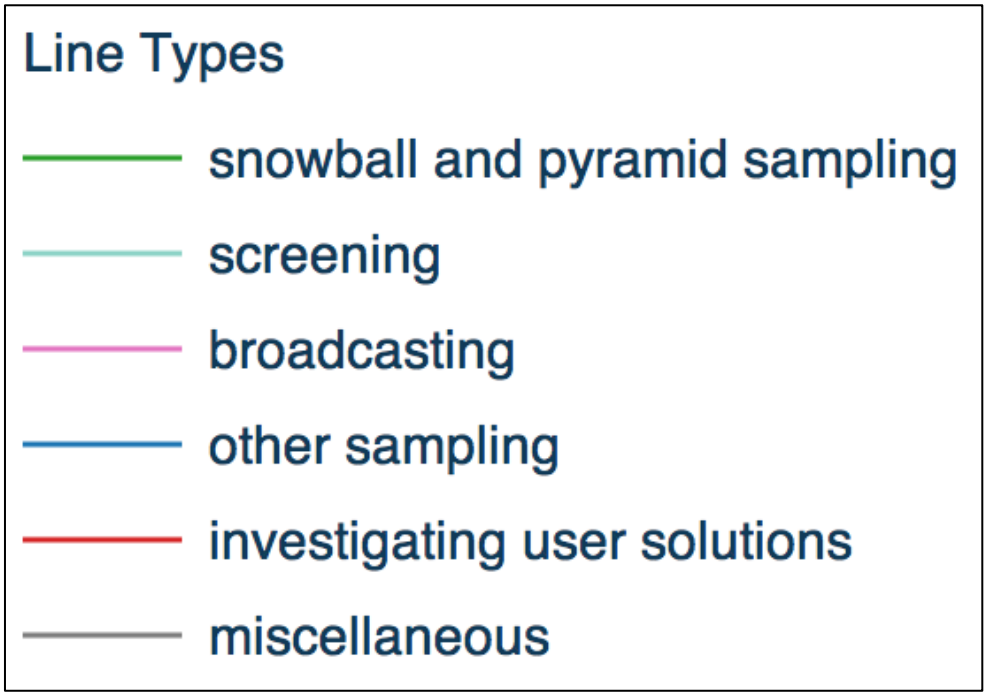


Figure 12. Line types in the graphs, elaborated in section “Approaches to Rare Subject Identification”.

# Appendix C

Table 5. The variation of the used methods, starting points, and identified leads of the four principal cases.

| | **Web Service for Teachers** | **Solar Panels** | **Wood Pellets** | **Solar Thermal Collectors** |
|---|---|---|---|---|
| **Use of Methods** | | | | |
| Snowball and pyramid sampling | 16 | 15 | 16 | 17 |
| Screening | 0 | 1 | 3 | 2 |
| Broadcasting | 12 | 0 | 0 | 0 |
| Other sampling methods | 5 | 12 | 6 | 4 |
| Investigating user solutions and investments | 5 | 2 | 1 | 1 |
| Miscellaneous encounters | 3 | 4 | 1 | 0 |
| *Total* | *41* | *34* | *27* | *24* |
| | | | | |
| **Starting points** | | | | |
| Personal network | 2 | 2 | 1 | 1 |
| Organization | 0 | 1 | 0 | 0 |
| Media | 1 | 0 | 1 | 0 |
| CMC | 1 | 0 | 0 | 0 |
| Index | 5 | 1 | 2 | 1 |
| *Total* | *9* | *4* | *4* | *2* |
| | | | | |
| **Leads** | | | | |
| Person | 33 | 42 | 51 | 35 |
| Organization | 33 | 13 | 4 | 4 |
| Event | 0 | 3 | 0 | 0 |
| Media | 1 | 0 | 0 | 0 |
| Solution | 24 | 1 | 0 | 0 |
| CMC | 22 | 7 | 6 | 4 |
| Field | 2 | 0 | 0 | 0 |
| *Total* | *115* | *66* | *61* | *43* |

Aalto-ST 7/2013

ISBN 978-952-60-5111-6 (pdf)
ISSN-L 1799-4896
ISSN 1799-4896
ISSN 1799-490X (pdf)

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